Study on Mimo Arrays Optimization

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Abstract

Aiming at the problem about antenna element numbers optimization of long baseline MIMO radar, this paper analylizes the problem by the probability of detection. A detection model is deduced, and a simulation flow is designed. Simulated experimentations are carried out based on different array configurations, and an optimization suggestion is obtained about antenna element numbers of long baseline MIMO radar.

Keywords

MIMO Radar; Antenna Element; Optimization

Introduction

In Multiple-input Multiple-output (MIMO) radar, several antenna elements transmit several orthogonal waveforms synchronously, and several antenna elements receive echoes. Based on Spatial Diversity, MIMO radar takes advantage of counteracting target scintillations. In the conventional radar, targets generally consist of many small scatterers that are fused by the radar waveform, to result in echoes with fluctuating amplitude and phase. And slow fluctuations of the target Radar Cross-Section (RCS) result in target fades that degrade conventional radar performance[0]. By spacing the antenna elements at the transmitter and at the receiver widely, MIMO radar can exploit the spatial diversity of target scatterers obtaining steady RCS that can improve radar performance. But how many antenna elements at the transmitter and at the receiver does MIMO radar place, in order to get most advantages? Few reports answer this question. This paper focuses on the problem based on the long baseline MIMO radar. A detection model is deduced, and a simulation flow is designed. Simulated analysis is carried out by the probability of detection, and an optimization suggestion is obtained about antenna element numbers.

Detection Model

MIMO radar system is composed of M transmitters and N receivers. Echoes from N receiver units can be divided into MN signals through matched filters. In particular, the spacing between the elements of the long baseline MIMO radar is very large, so signals are independent, and the detector combines these signals noncoherently. By the narrow-band signal assumption, the received signals can be accumulated synchronously from different elements.

The transmitted signals are

$$\mathbf{s}(t)=\left[s_1(t),\cdots,s_M(t)\right] \tag{1}$$

here, the transmitted signals are orthogonal each other. $\mathbf{r}_k(t)$ is the received signals of each received element, and

$$\mathbf{r}_k(t)=\sqrt{\frac{E}{M}}\boldsymbol{\alpha}_k^H\mathbf{s}(t-\tau)+\mathbf{n}(t),\quad k=1,\cdots N \tag{2}$$

here, $\boldsymbol{\alpha}_k \propto CN(0,\mathbf{I}_M)$.

$y_i(t)$ is the output of a bank of matched, and

$$y_i(t)=\int \mathbf{r}_k^H(t)s_i(t-\tau)dt,\quad i=1,\cdots,M \tag{3}$$

So

$$\mathbf{Y}_k(t)=[y_1(t),y_2(t),\cdots,y_M(t)]^T \tag{4}$$

For the long baseline MIMO radar, echoes are independent, and the test statistic is

$$T=\sum_{k=1}^{N}\left\|\mathbf{Y}_k(t)\right\|^2 \tag{5}$$

The probability of detection is

$$P_D=P_r\left(T>\delta\middle|\text{target existence}\right) \tag{6}$$

here, δ is the detection threshold.

The primary aim of Radar is detection, so the probability of detection can be an evaluated index to compare the performance of different MIMO arrays.

Simulation Flow

As known to us，in the long baseline MIMO radar, the

performance of detection is excellent because of spatial diversity0. But in traditional radar, the performance of detection is improved with receiver element numbers increasing. So, how many antenna elements at the transmitter and at the receiver do the long baseline MIMO radar place, in order to get most advantages? Aiming at the problem, a simulation flow is designed (Fig.1). The conclusion will be obtained based on the performance of detection by simulated experimentations.

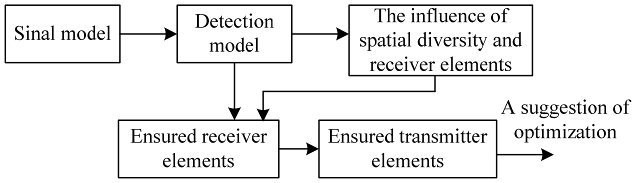

FIG.1. A SIMULATION FLOE

Simulated Results and Analysis

This section carries out simulations based on the upper simulation flow. The total transmitted energy is settled, and MIMO radar is a long baseline.

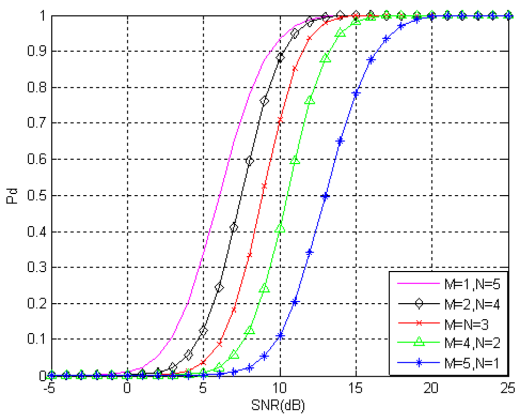

FIG.2. THE PROBABILITY OF DETECTION WITH VARIOUS M AND N

In fig.2, the total elements are settled, and the probability of detection curves are based on different antenna element numbers at the transmitter and at the receiver. From fig.2, the performance of detection is improved with receiver element numbers increasing. When $M=1$ and $N=5$, the performance of detection is best. Whereas, the signal paths are maximum when $M=3$ and $N=3$ .This proves, the influence of receiver element numbers to the probability of detection is greater than the signal paths in the MIMO radar.

Fig.3 depicts the probability of detection for various receiver element numbers in MIMO radar, where $M=1$. It is evident from the figure that, the MIMO radar performance is better as receiver element numbers increase. When the receiver element number is more than five, the spacing between different curves change slowly.

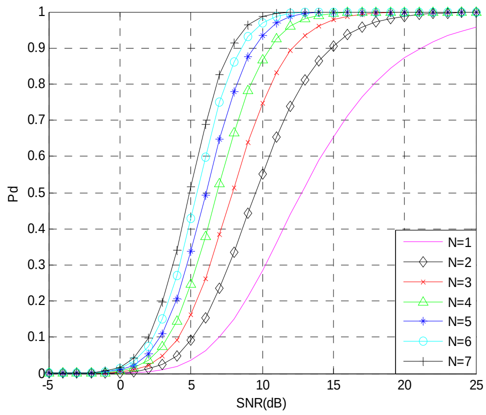

FIG.3. M=1, THE PROBILITY OF DETECTION WITH VARIOUS N

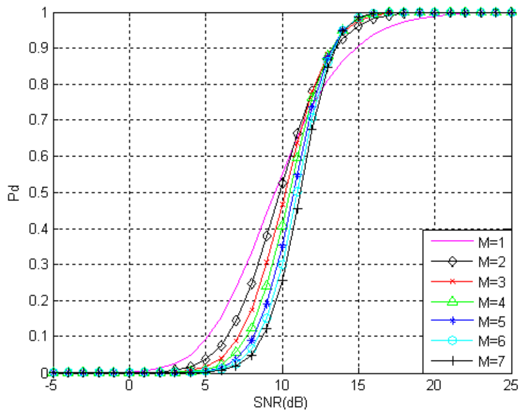

FIG.4. N=5, THE PROBABILITY OF DETECTION WITH VARIOUS M

Fig.4 depicts the probability of detection for various transmitter elements in MIMO radar, where $N=5$. It is evident from the figure that, for high SNR the MIMO radar performance is better as transmitter element numbers increase, and is worst as $M=1$. For low SNR the MIMO radar performance is better as transmitter element numbers decrease, and is best as $M=1$ .When the transmitter element numbers are more than $M=3$,the spacing between different curves change slowly. For high SNR, several transmitter elements are better than the single transmitter element, because MIMO radar exploits spatial diversity to overcome target fading. For low SNR, the single transmitter elements are better than several transmitter elements, because the instantaneous SNR is higher compared with the average SNR. From fig.3 and fig.4, considered of the performance and engineering price, the suggestion is

$M = 3$ and $N = 5$ for the long baseline MIMO radar.

Conclusions

Based on the detection model of the long baseline MIMO radar, this paper analyzes antenna element number optimization by the performance of detection. Certainly, this paper analyzes the optimization problem according to the detector's performance and engineering price, and if analyzed from other requirements, different results may have been gotten.

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